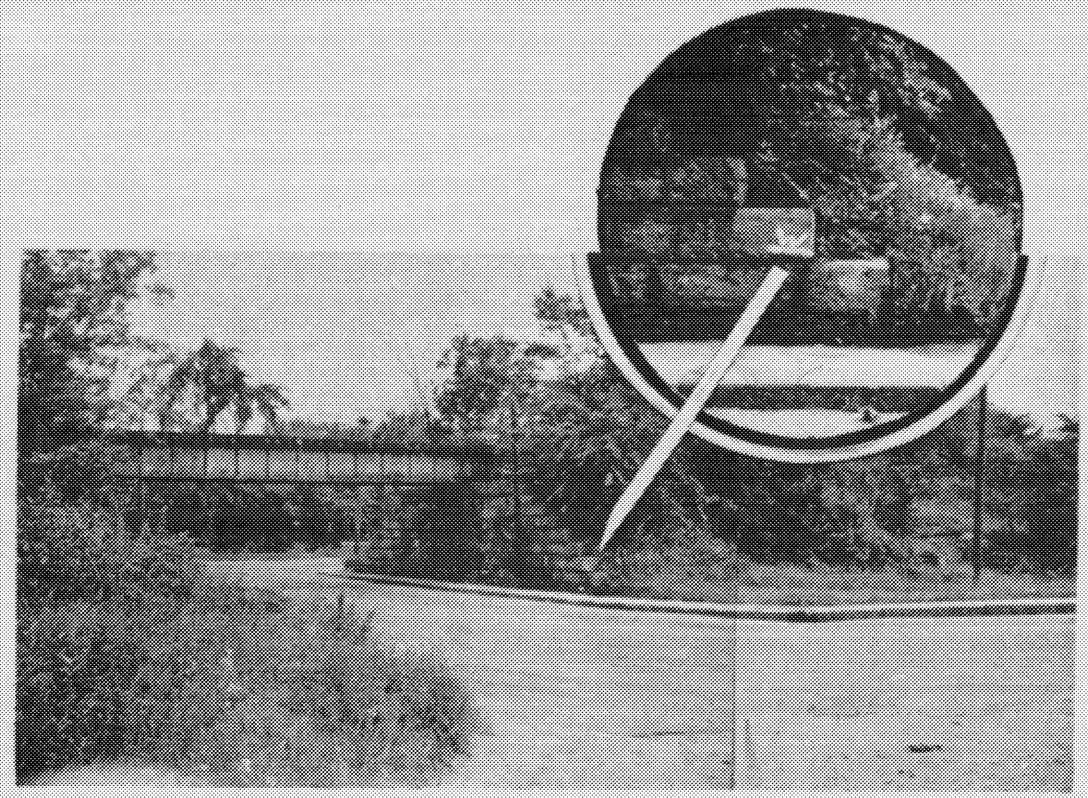
FLOOD PLAIN INFORMATION

FILE COPY

CHARLES RIVER

MEDWAY
MASSACHUSETTS



PREPARED FOR
THE TOWN OF MEDWAY
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS
AUGUST 1967

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INTRODUCTION

Purpose of the Study: The information presented in this report will provide a technical basis for evaluating the potential flood threat along the Charles River in the Town of Medway, Massachusetts, associated with increased development of the flood plain areas. For 29 years discharge and rainfall records for the Charles River have been collected by the U. S. Geological Survey. This report will relate these records to the existing topography and present conclusions which will provide a basis for further study, planning and action by State and local interests in alleviating existing flood problems. It will also provide technical data which will make possible optimum economic use of the areas subject to flooding based on carefully considered local judgment and the exercise of control of the development of such areas. This report is intended to encourage those affected to undertake and carry out programs to help themselves.

Authorization: The authority for this study is derived from Section 206 Public Law 86-645 (Flood Control Act of 1960, approved July 14, 1960) and first endorsement dated August 12, 1965 to NED letter dated August 10, 1965, subject: "Application for Flood Plain Information Studies, Charles River, Medway, Massachusetts. Section 206 Public Law 86-645 reads as follows:

"SEC. 206(a). That, in recognition of the increasing use and development of the flood plains of the rivers of the United States and of the need for information on flood hazards to serve as a guide to such development, and as a basis for avoiding future flood hazards by regulation of use by States and municipalities, the Secretary of the Army, through the Chief of Engineers, Department of the Army, is hereby authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods of various magnitudes and frequencies, and general criteria for guidance in the use of flood plain areas; and to provide engineering advice to local interests for their use in planning to ameliorate the flood hazard:

Provided, That the necessary surveys and studies will be made and such information and advice will be provided for specific localities only upon the request of a State or a responsible local governmental agency and upon approval by the Chief of Engineers."

This report has been reviewed and approved for release by the Town of Medway, Massachusetts Water Resources Commission and by the Division Engineer, New England Division, Corps of Engineers.

Scope of Study: The specific area of this study runs from the Millis Town Line downstream of Populatic Pond to the Bellingham Town Line at Hopping Brook, a distance of approximately 5.8 miles.

As a result of rainfall associated with Hurricane Diane on August 18 and 19, 1955, there was considerable flooding in this area. It was the maximum known flood for the area and far surpassed either the March 1936 or July 1938 floods. Since regulations for flood plains should recognize the varying degrees of risk, two lesser floods were developed. The result of the two computed floods are shown together with the floods of 1955 and 1936 in the maps profiles and cross-sections. The two flood stages computed represent magnitudes of 25 percent and 60 percent less than the August 1955 flood.

Use of Study: The maps, profiles and cross-sections show the extent and depths of flooding. From this data future land development may be planned, either high enough to assure the avoidance of damage or at a lower elevation with recognition of the chance and hazards of flooding.

It must be borne in mind that the hydraulic computations reported herein are based on the present topography of the watershed and as development proceeds, the runoff rates for any given storm will tend to increase.

It is not intended to extend any Federal Authority over zoning or other regulation of flood plain use. Furthermore, this report is not to be construed as committing the Federal Government to investigate, plan, design, construct, operate or maintain any facilities discussed or to imply any intent to undertake such activities if not authorized by Congress.

It is the responsibility of the State and local agencies to make available the information in this report to planning groups, zoning boards, private citizens, engineering firms, business firms, real estate developers, financial institutions and industries. Additional copies may be obtained from the Town of Medway Planning Board, Town Hall, Medway, Massachusetts.

__Acknowledgements:__ Appreciation is extended to all of the individuals who privately or as representatives of the industries in the area were helpful in developing the field data. The cooperation and assistance of other federal and non-federal agencies in observing, collecting and compiling the information contained herein are also appreciated. Some of these agencies are the following:

U. S. Geological Survey

U. S. Weather Bureau

Massachusetts Department of Public Works, Bridge Division

Massachusetts Geodetic Survey

Town of Medway Highway Department

Continued Assistance of the Corps of Engineers: This report was prepared by Green Engineering Affiliates, Inc., Boston, Massachusetts, under the direction of the New England Division, Corps of Engineers, located in Waltham, Massachusetts. Representatives from the Corps of Engineers will be available upon request of State and local governmental agencies to explain information in this report and to provide other pertinent data which are available.

DESCRIPTION OF PROBLEM

Location: Medway, Massachusetts, is in the southeast part of the Commonwealth about 25 miles southwest of Boston. (See Location Map, Plate No. 1) It is bounded on the west by Milford, on the north by Holliston, on the east by Millis and on the south by Franklin and Bellingham. The Charles River enters the town at its southwest corner at Hopping Brook which forms the Bellingham-Medway Town Line, it then flows along the southern side of the town forming the Medway-Bellingham and the Medway-Franklin Town Lines, from there it flows into Populatic Pond and leaving the Pond it flows easterly to the Medway-Millis Town Line.

Drainage Area: The Charles River has a drainage area at the Medway-Millis Town Line of approximately 65 square miles. The watershed is approximately 8 miles wide in the East-West direction by 10 miles in the North-South direction and is roughly rectangular in shape. The area at the western and northern parts of the watershed is moderately hilly land while the eastern and southern parts are in the order of rolling pasture land and some wooded and swampy areas. The watershed contains a number of ponds and lakes, the largest lake being Echo Lake at the headwaters of the river in Hopkinton and Cedar Swamp Pond in Milford.

Basin Description: The upstream reaches of the basin have a fairly rugged terrain and are largely wooded. The central portions are occupied by the Towns of Milford, West Medway, Medway and the Town of Bellingham where many large single family housing developments have sprung up. On the Franklin side of the river the land is mostly cleared farm land with some housing development. Echo Lake and Cedar Swamp Pond both tend to dampen the peak flows at the downstream reaches of the river during times of severe storms.

The major tributaries to the Charles River in the area of this study are in their order of magnitude, Hopping Brook, Mine Brook, Shepards Brook, and Chicken Brook. Hopping Brook lies in the northwest portion of the watershed and has a drainage area of approximately 11 square miles. The area through which it flows is moderately hilly and drops about 120 feet in its 8 miles of length. It is dotted with small ponds and has a rather wide swampy flood plain for its entire length. Mine Brook has many of the same characteristics as Hopping Brook except there are a number of large ponds along its length. It has a swampy flood plain which is considerably narrower than that on Hopping Brook and drops about 160 feet in its 12 miles of length. Shepards Brook is a short stream with practically no flood plain. It drops about 110 feet in its 3 miles of length and offers little or no storage for its entire length. Chicken Brook flows southerly through West Medway Center to the Charles River. It flows for the most part through moderately hilly terrain north of the town. Although it drops about 130 feet over its length of 8 miles, it is nevertheless characterized by moderately wide swampy flood plains just north of the town. At the north side of town it flows into an artificial pond which is used for recreation by the Town of Medway and then flows under Route 109 and under the United Shoe Machinery factory. The underpassed structures offer quite a large restriction to flow and causes most of the flooding of this brook at this point.

Another outstanding feature in the area of this study is Populatic Pond which lies in the Town of Norfolk at the Medway-Franklin Town Line. This pond and the adjoining Great Black Swamp serve as a large storage area during the time of severe storms.

Flood Plain Description: The portion of the Charles River flood plain which is the subject of this report extends from the Medway-Millis Town Line just downstream of Populatic Pond to the Medway-Bellingham Town Line at Hopping Brook, a distance of 31,000 feet. Its total fall in the area under study is only 40 feet. Throughout its length it is a slow meandering stream with a varying flood plain from no flood plain at all at the Sanford Street area where the river runs through a deep gorge to a flood plain of about 300 feet in width between Franklin Street and Hopping Brook. To the west there are extensive swamps and ponds but many of these natural storage areas are being rapidly developed for housing. For the most part the flood plain that does exist has grown up to brush and small trees with grass in the swamp areas.

Development in the Flood Plain: Generally, there are only a few places along the flood plain where previous storage areas have been filled. One of them is along Pond Street on the Franklin side of the river where new home construction in the past decade has caused a large area to be filled and restricts the river to a very narrow channel. Another is along Shaw Street on the Medway side where the same situation occurs. The homes now standing on the filled-in flood plain in this location are subject to flooding in all cases except the 10 percent annual occurence floods. There are many homes and buildings in the "Populatic" area of the river on Village Street and adjacent streets which have a history of being flooded by floods of even minor proportions. There are numerous dams and bridges in this section of the flood plain, all of which were constructed many years ago.

Bridges: All bridges crossing the river are restrictions to flood flow but the degree of restriction varies greatly between bridges and between discharges. The restrictive effect of each bridge is shown on the flood profile by the drop in water surface elevation at each bridge.

Table I lists pertinent elevations for the bridges and shows their relation to the Intermediate Regional Flood and the Maximum Known Flood, August 1955.

A. The bridge carrying Bent Street over the river is a steel truss bridge with a wood deck supported by stone abutments. The head losses will be negligible for floods or lesser stages. For the Intermediate Regional Flood and the Maximum Known Flood the river will flow around the bridge with a resultant minimum head loss. (Photo I)

TABLE I

BRIDGES ACROSS CHARLES RIVER

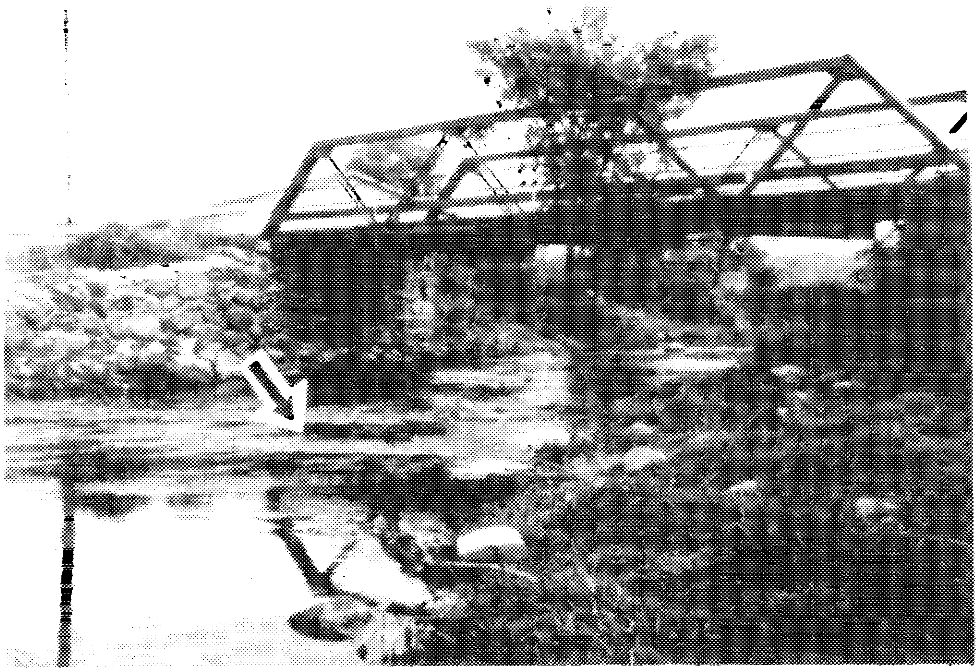
Station	Identification	Stream Bed Elev.	Floor Elev.	Intermediate Regional Flood Crest	August 1955 Flood Crest	Underclearance: Elev.	Underclearance: Relation to Intermediate Regional Flood: Above	Underclearance: Relation to Intermediate Regional Flood: Below
		M. S. L.	M. S. L.	M. S. L.	M. S. L.	M. S. L.	feet	feet
191+00	Bent St.	128.0	140.5	138.5	139.5	138.5	0.0	
224+50	Sanford St.	143.0	173.0	153.8	154.7	171.0	17.2	
311+50	Shaw St.	158.3	172.5	169.0	170.0	170.0	1.0	
363+00	Franklin St.	167.0	181.0	178.2	179.8	176.0		2.2

B. The bridge carrying Sanford Street over the river is a stone and concrete arch bridge with ample vertical clearance. At low flows it has no effect on flooding. At higher flows it introduces only a slight restriction due to its close conformity with the contours of the river bed in this location (the river flows through a rather deep and narrow gorge in this vicinity and the gorge itself presents some restriction). (Photo 2)

C. The bridge at Shaw Street is a stone arch bridge in combination with a stone box culvert. This bridge and culvert slightly restrict the flow at low flood stages, while the larger floods flow around it at a low point in the road just north of the bridge presenting a minimum restriction. (Photo 3)

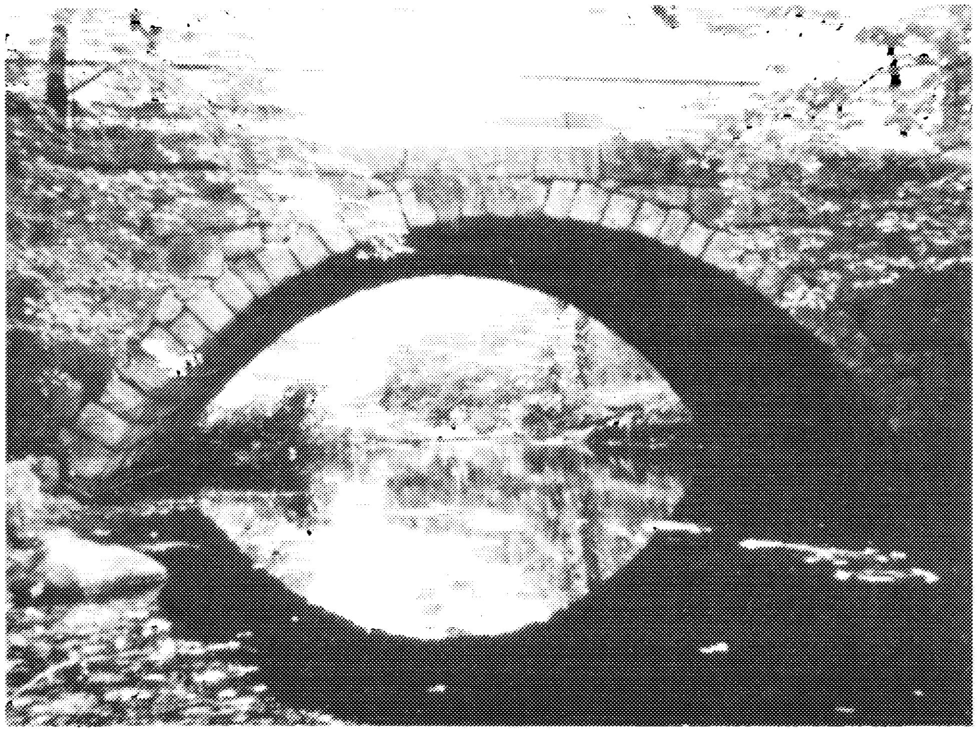
D. The bridge at station 334 + 80 which carries a private road across the river is a wooden bridge on stone abutments with concrete and wooden piers. This bridge has little effect on the flood level and in all probability will be washed out and by-passed through a low point in the road north of the bridge by any flood of consequence. (Photo 4)

E. The bridge carrying Franklin Street across the river is a dual stone arch bridge. This bridge presents little restriction at the lower flood stages but at the higher flood



#1 Bent Street Bridge With Remains Of Earthen Dam In Foreground. (Arrow)

#2 Sanford Street Bridge With Medway Woolen Mills Dam In Background



#3 Stone Arch Bridge At Shaw Street

#4 Bridge At Station 334+80

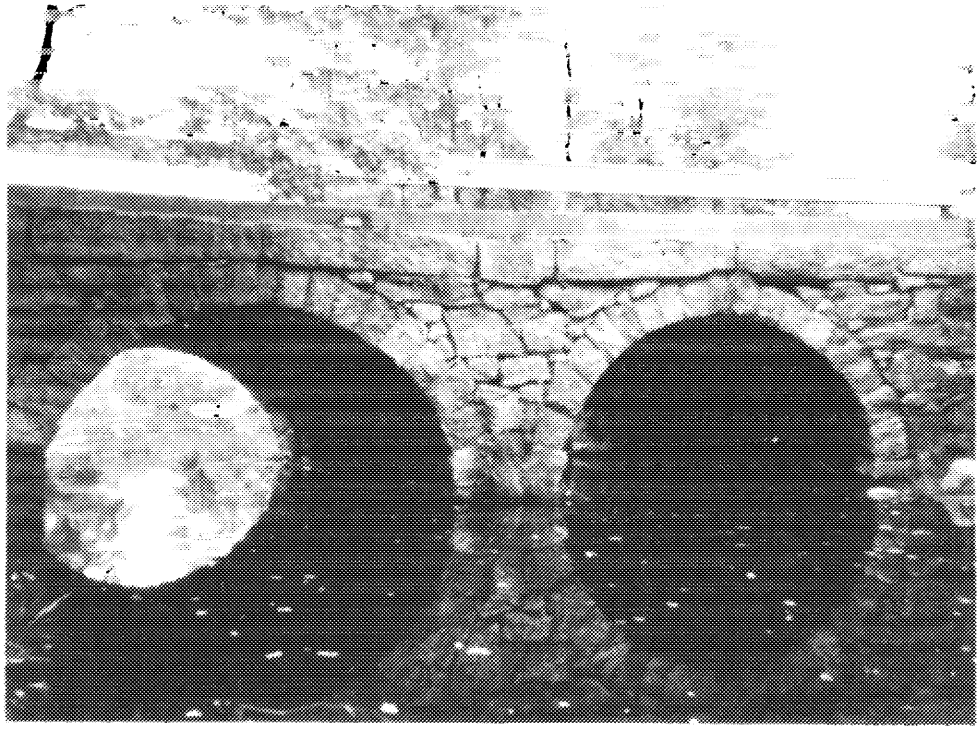
stages there is quite a large head loss, due in part to the fact that the bridge will be almost overtopped, and the structure is quite bulky. (Photo 5)

F. At Station 175 + 00 there is an abandoned railroad bridge with only the stone abutments remaining. These abutments present little restriction at any of the flood stages.

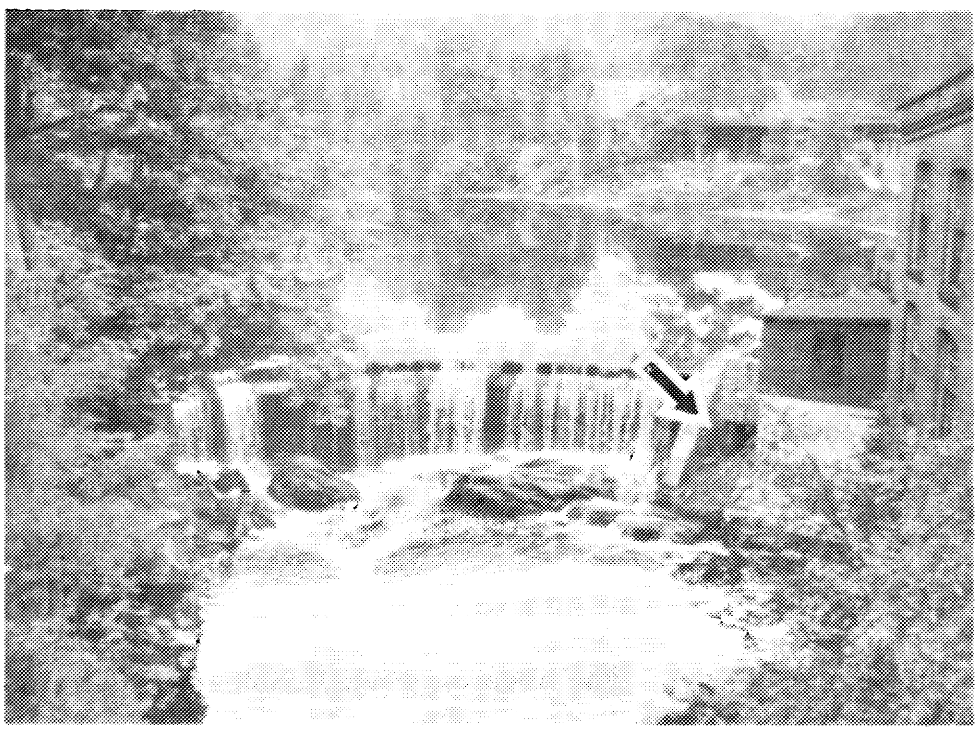
Dams: There are two dams within the area of this study and the remains of another dam. There is also a dam just upstream from the upstream limit of the study.

A. The dam upstream of the Bent Street Bridge has been removed and the area presents no restriction other than those already discussed for the bridge. (Photo 1)

B. The dam at Medway Woolen Mills is a concrete dam with two 4 foot square gates and a 6 foot by 8 foot gate to the mill wheel house. At the present time, the spillway elevation has been raised 18 inches by means of stop logs across the entire length of the spillway. Any flood of consequence would, however, wash out these logs. The length of the spillway is 68 feet. Its elevation (minus the stop logs) is 159.3 feet. With both 4 foot square gates closed and the gate to the wheel house open, the water surface elevation upstream of the spillway for the Maximum Known Flood was 165.4 feet. (Photos 2, 6 & 7)



#5 Twin Arch Stone Bridge At Franklin Street

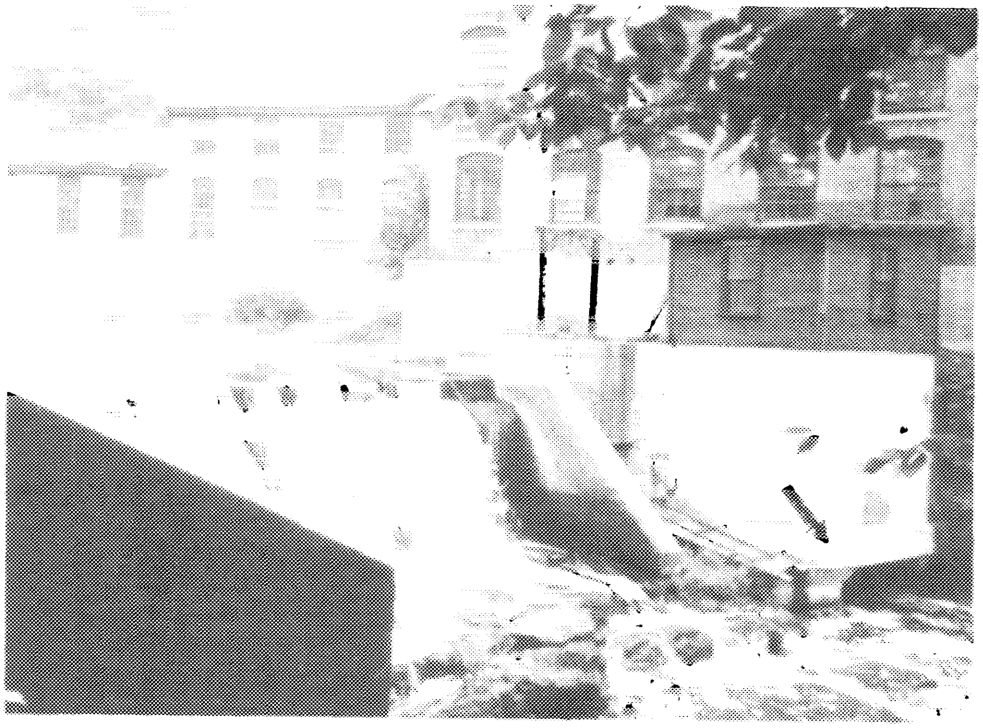


#6 Medway Woolen Mills Dam Showing 4 ft. sq. gates At North Abutment (arrow)

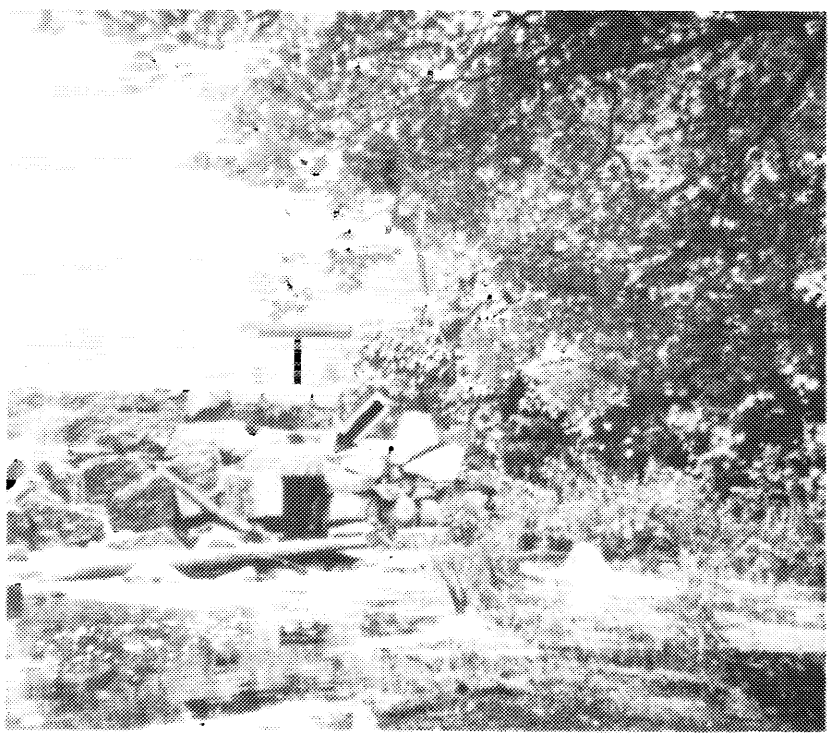
C. The West Medway or Woodside Dam at station 341 + 00 is a stone dam with a concrete north abutment and an earthen south abutment. There is a 2 foot by 7 feet opening through the face of the dam which is largely blocked by logs and debris. There are also two sluiceways circumventing the north abutment of the dam. One of these sluiceways has a wood gate which in all probability will be washed out by either the Intermediate Regional Flood or the Maximum Known Flood. The spillway is 81 feet long with a crest elevation of 169.7 feet. The water surface elevation upstream of the spillway for the Maximum Known Flood was 176.0 feet. (Photo 8)

D. The dam at the Roaring Brook Spinning Mills is not within the limits of this study; however, the flow over it must be considered as contributing to flows within the study area. A flood profile prepared by Howard M. Turner indicates that the flow through this area for the 1955 flood was approximately 2200 cfs.

Vegetation Encroachments: Some of the stream banks are covered with brush and trees and in the swampy areas the prevalence of heavy marsh vegetation is evident. The area between Franklin Street and the West Medway Dam has a heavy growth of trees and brush on both banks. (Photo 9) The same is true of the area between Shaw Street and the Medway



#7 Medway Woolen Mills Dam Showing Outlet From Wheel House (arrow)

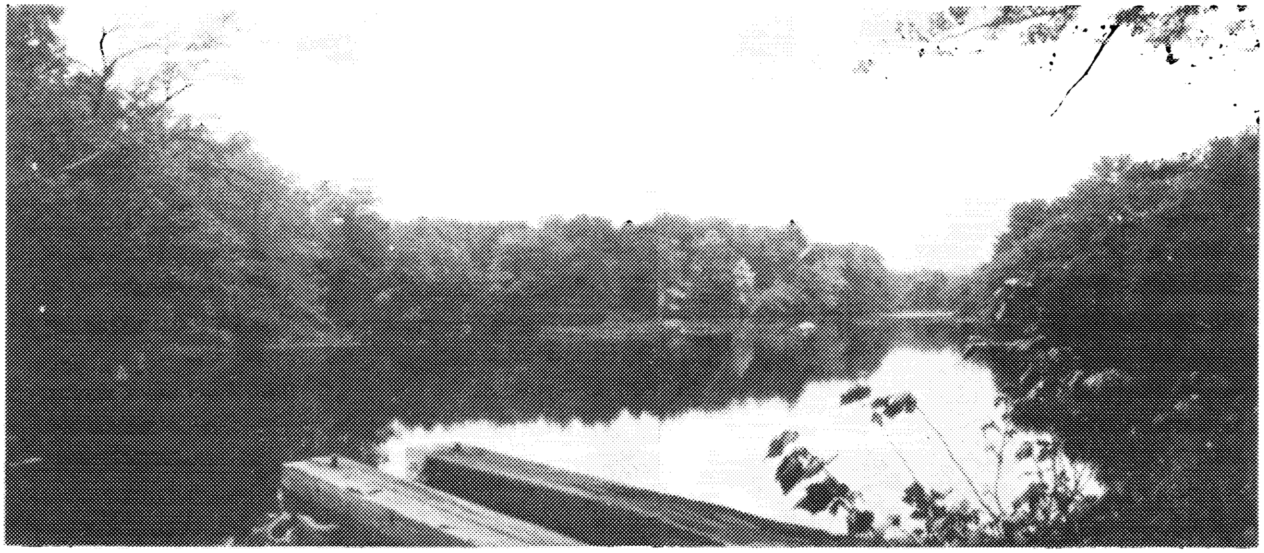


#8 West Medway (Woodside) Dam Showing Blocked 2 ft. x 2 ft. Opening (arrow)

Woolen Mills Dam. (Photos 10 & 11). Downstream of Bent Street, the river flows through a grassy plain until it enters a swampy area about 1500 feet upstream of Populatic Pond, (Photo 12). The wooded and grown-over areas also show evidence of fallen trees and other debris in the channel. In these areas there is a tendency toward high flow resistance resulting in higher flood levels than would be obtained if a clearer flood channel existed.

Flood Damage: There is no evidence of any of the permanent bridges being washed out in either the flood of March 1936 or the flood of August 1955. Many of the homes along the river were flooded during the August 1955 flood. However, most of this flooding was confined to the basements except in the Populatic area where the worst flooding occurred. There is no record of any of the dams giving way during either of these floods, but it has been reported that the Medway Woolen Mills Dam was on the verge of being breached during the August 1955 flood.

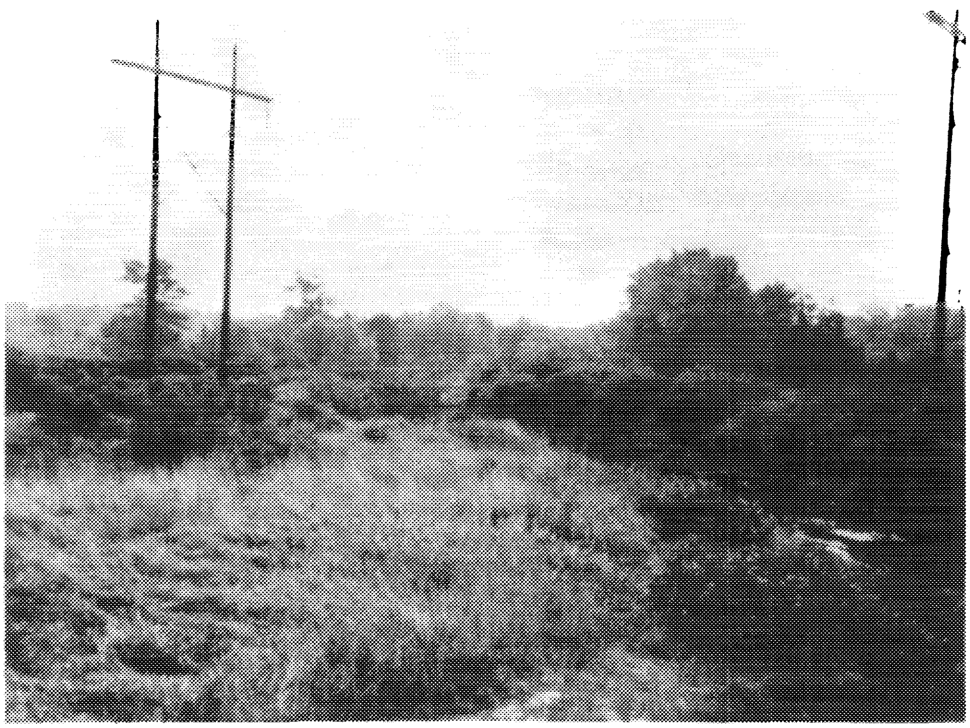
Flood Warning and Forecasting: The Town of Medway should formulate plans by which persons living in the flood plains can be warned of impending floods, so that they may have time to protect themselves and their property in advance of the flood. The U. S. Weather Bureau is the agency responsible for flood forecasting.



#9 Reservoir Behind West Medway Dam

#10 Marsh Vegetation Upstream Of Shaw Street Bridge

#11 Vegetation Encroachment Downstream Of Sanford Street Bridge, Showing Rocks and Debris In Channel.



#12 Typical Flood Plain Downstream Of Bent Street Bridge

Existing Regulations: The Town of Medway does not have, at the present time, any local laws which regulate filling or construction in the flood plain. However, the Commonwealth of Massachusetts has enacted a Zoning Enabling Act, Chapter 404 of the General Laws, by Chapters 368 and 551 of the Acts of 1954, Section 2 of this Act states the following:

> "A zoning ordinance or by-law may provide that lands deemed subject to seasonal or periodic flooding shall not be used for residence or other purposes in such manner as to endanger the health or safety of the occupants thereof. . . . ."

BASIC DATA

Surveys: A detailed reconnaissance was made of the Charles River from the Myrtle Street bridge in Millis to the Roaring Brook Spinning Mills dam in Careyville. During this reconnaissance all restrictions to the flow of the river were identified, classified hydraulically and photographed. Intermediate points which would establish hydraulic frictional coefficients (Manning's "n") were also located. Horizontal control for cross sections was established from enlargements of the United States Coast and Geodetic Survey quadrangle maps. A survey party then made ten detailed and accurate cross sections at bridges and other points established in the reconnaissance, running vertical control for the section under study but using the horizontal control from the United States Coast and Geodetic Survey quadrangles. Four of these sections, which are considered typical, are plotted on plate 10. The following Massachusetts Geodetic Survey Bench Marks were recovered and used for vertical control:

TBM CSR 32 — Elev. 179.58
Cut chiseled in west end of north abutment of Franklin Street Bridge

TBM CSR 33 — Elev. 172.69
Cut chiseled in west side of Shaw Street Bridge over north end of arch.

TBM CSR 34 — Elev. 213.44
Top of east granite post on west walk of Catholic Church on Village Street at center of Medway. No mark.

TBM CSR 37 — Elev. 139.64
Cut in west end of north abutment of Bent Street Bridge

TBM CSE 38 — Elev. 137.05
Cut in west end of north abutment of Myrtle Street (Millis) Bridge.

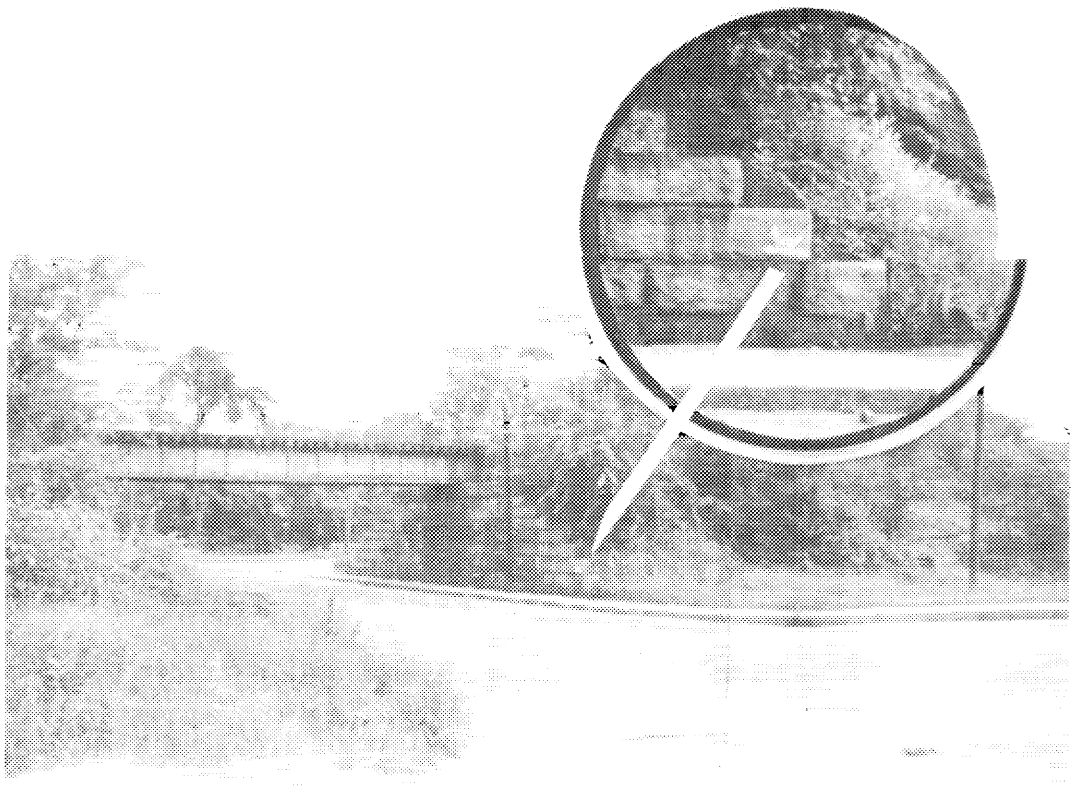
Mapping: The maps of the flood plain were traced from photostatic enlargements of the quadrangle sheets. Adjustments to these maps were made from information gathered during the reconnaissance and the field survey.

Profiles: The center line stationing used to develope the profile was scaled from the photostatic enlargements of the quadrangle sheets. Elevations of the bottom of the river and the tops of banks as well as the vertical location of bridges and dams were developed from the surveyed cross sections with intermediate points developed from the enlargements of the quadrangle sheets. The high water data for the August 1955 flood were obtained during field investigation. (Photo 13)

Discharge Records: There are no discharge records available for the section of the Charles River considered in this study. However, the U. S. Geological Survey maintains a gaging station at Charles River Village on the Charles River, approximately 21 miles below the Medway-Millis Town Line. The drainage area above this gage is 184 square miles.

Peak discharges used in this study were developed from records of Charles River Village Gage, hourly rainfall records of Hurricanes Connie and Diane in August 1955, and the recorded high-water marks of the March 1936 flood.

Storage in Populatic Pond, Great Black Swamp, Maple Swamp, and in the large, low flood plain between Populatic Pond and Dover; and the addition of 116 square miles of watershed so modify the flow at the gaging station that the records could not be directly translated to the sections of the stream under consideration. It was necessary, therefore, to develope the discharge computations for the study area on the basis of Benson's Data (Water Supply Paper 1580-B), and the Rational Method.



#13 High Water Mark (arrow) for August, 1955 Flood at Railroad Bridge over Village Street.

PRECIPITATION AND FLOODS

Precipitation: Precipitation records for the watershed in question are few and far between. For this reason, run-off computations have been developed from the basin characteristics following Geological Survey Water Supply Paper 1580B and using the gaging station at Charles River Village.

Precipitation data for the March 1936 flood were obtained from an average of meteorological stations at Framingham and Ashland, and data for the two hurricane floods of August 1955 were obtained from a U. S. Weather Bureau precipitation record at Mendon. The data for the two 1938 storms were obtained from the records of the U. S. Weather Bureau precipitation station at Millis.

The following tabulation taken from U. S. Weather Bureau Technical Paper No. 26, Massachusetts Geodetic Survey Study "High Water Data, Flood of March 1936 in Massachusetts" and the precipitation records of the U. S. Weather Bureau gives the approximate precipitation over the watershed above Populatic Pond for the most recent large storms.

TABLE II

STORM PRECIPITATION (inches)

Date			Precipitation
March	11-21,	1936	6.7
March	22-31,	1936	1.8
July	18-24,	1938	9.6
Sept.	17-22,	1938	6.0
August	11-16,	1955	2.6
August	17-20,	1955	15.1
August	22-28,	1955	2.7

The daily rainfall breakdown for the 1955 storms is shown in a later section..

For comparison purposes the expected precipitation on a frequency of occurrence basis is taken from the Rainfall Frequency Atlas of the United States, Weather Bureau Technical Paper No. 40 and from U.S.G.S. Water Supply Paper 1580-B.

TABLE III

ANTICIPATED PRECIPITATION (inches)

Duration of Storm	Annual Probability			
	10%	4%	1%	.33%
1/2 Hour	1.5	1.8	2.2	2.8
1 Hour	1.9	2.2	2.8	3.2
2 Hours	2.3	2.7	3.3	3.8
3 Hours	2.7	3.1	3.8	4.8
6 Hours	3.2	3.8	4.7	5.8
12 Hours	3.9	4.7	5.8	7.5
24 Hours	4.8	5.8	7.5	8.7

Floods: Flooding in any river occurs when the inflow in any reach exceeds the bank-full discharge capacity. Once this condition has been reached, greater inflows will result in storm flows going into storage in the flood plain and an increase in the discharge rate. Each flood has its own characteristics based on the condition in the watershed at the time of the flood and the rate and duration of the rainfall. Two diverse examples are the flash floods which result from high rainfall intensity over a short period of time, and great floods which result from long continued rates of rainfall in excess of the stream capacity. The August 1955 flood is an example of a flash flood and the March 1936 flood is an example of a great flood. Flash floods are most damaging on a small watershed, such as the watershed under study here.

The Floods of March 1936 and August 1955: The floods of March 19 and 20, 1936 resulted from a combination of deep snow; thick ice cover on all waterways; long continuing heavy rains and abnormally high temperatures. The estimated peak discharge downstream of Populatic Pond was 1500 cubic feet per second. While the flood of March 1936 was a serious and damaging flood in this watershed, it was dwarfed by the extent of flooding experienced in August 1955.

The flood of August 18 and 19, 1955 caused extensive damage in this area as it did throughout most of southern New England. This flood resulted from rainfall associated with Hurricane Diane. Over 13 inches of rain fell on ground saturated by almost 3 inches of rain which fell less than a week previous when Hurricane Connie swept through the area.

Streams and reservoirs in this area were already running higher than normal due to Hurricane Connie when precipitation from Hurricane Diane began in the early morning hours of August 18. Heavy rain fell for more than 30 hours without interruption. During the 38 hour period from 6:00 A. M. on August 18 to 9:00 P. M. August 19, 13.20 inches were recorded at the Mendon precipitation station just west of the study area. This rainfall produced an estimated peak flood discharge of 3150 cubic feet per second downstream of Populatic Pond - more than double that of the previous maximum recorded flood of March 1936. The following is a breakdown of the daily precipitation records for the period of August 11 to August 20, 1955 for the precipitation station at Mendon, Massachusetts.

Date	Precipitation (inches)	
August 11	0.14	Hurricane Connie
12	1.02	
13	1.11	
14	0.0	
15	0.0	
16	0.0	
17	0.63	Small storm ahead of Hurricane Diane
18	4.91	Hurricane Diane
19	8.29	
20	0.0	
Total	16.10	

Flood Frequencies: The term "flood frequency" is used to denote the percent chance of occurrence of a given flood. The percent chance occurrence is developed from statistics of the flood history of the region. It is generally referred to an annual basis or percent chance in any one year. Thus a "10 percent annual probability flood" is a flood which has a 10 percent chance of occurring in any one year. Floods of lesser magnitude have a high flood frequency or percent chance, whereas a large flood has a low flood frequency, that is, a small chance of occurrence in any year.

Flood frequencies can be used as reasonable guides provided there is no major change in the hydrologic characteristics of the basin or in the hydraulics of the river channel.

Flood Analysis: The purpose of this study is to define the areas adjacent to the Charles River in Medway that are prone to flooding. The area and depth of flooding is directly related to the flood discharge which is a measure of the size of the flood. For this study, four floods were chosen for analysis, the flood of August 1955 and three smaller floods including the flood of March 1936 which may be of local interest. It is estimated that the flood of August 1955, the largest flood known, has a 0.33 percent chance of occurrence in any one year.

The next largest flood which is about 25 percent less than the 1955 flood has an estimated annual chance of occurrence of one percent. This is a major flood with a relatively frequent chance of probability. For purposes of identification the flood is called the Intermediate Regional Flood.

The 1936 flood is approximately 50 percent less than the 1955 flood and has a four percent annual chance of occurrence. The 10 percent annual probability flood analyzed is of a magnitude about 60 percent less than that of August 1955.

Standard Project Flood: Due to the variances in the flood history of streams in a given region, the Corps of Engineers has developed a standard to insure a consistant policy in the design of flood protection works such as dikes, levees and channel improvements. This is called a standard project flood. It is considered to be the largest flood that can reasonably be expected to develop with the coincidence of critical conditions that have been experienced in New England. It has been estimated that the standard project flood for the Charles River in the Medway area would be comparable to that experienced in August 1955. Therefore, no detailed study for this flood was developed.

Flood Routing: As stated previously, the Charles River Village gaging station provided the basic discharge frequency data for this study. A study of the difference in hydraulic characteristics between Charles River Village and the Town of Medway indicated that an area relationship alone would not be adequate. To account for the hydraulic dissimilarity between the gaging station and the study area, the factors from the analyses of New England rivers as published by the Geological Survey Water-Supply Paper 1580-B were used. Benson's Equation was implemented in determining discharges for all sections except those downstream of Populatic Pond. Since Benson's Multiple Correlation equation is not applicable to a location just below a reservoir, a hydrograph for the August 1955 flood (at a section just above Populatic Pond) has been developed, using the computed discharge over the Woolen Mill Dam, the Rational Method, the hourly rainfall records at Mendon, and assuming linear superposition. The outflow of Populatic Pond was then computed assuming prismatic storage routing through the pond.

The peak outflows at Populatic Pond for the 10 percent, March 1936 and Intermediate Regional Floods have been determined from a 24-hour unit hydrograph (see Graph 1) multiplied by the appropriate rainfall excess, plus a base flow determined from Benson's equation. This method is described in Davis' Handbook of Applied Hydraulics, Section 25.

The Rational Method: The rational method of determining run-off from small drainage areas is based on the premise that the peak rate of discharge is proportional to the rate of rainfall, modified by the size and characteristics of the area. The time of concentration is the time it would take rain falling on the most distant part of the drainage area to flow to the tail of that area.

Flood Profiles: The end product of this hydraulic analysis is represented by the Flood Profiles, Plate 9. These profiles show the stream bed, the stream banks, and the water surface elevations for the August 1955 flood, Intermediate Regional Flood, the March 1936 flood and the ten percent probability flood. The profiles reflect the hydraulic characteristics of the waterway at the present time, including the effects of bridges and dams.

Backwater Computations: The water surface profiles (see Plate No. 9) were developed from backwater computations employing the Escoffier* graphical method based on Bernoullis' energy theorem and

*Backwater Curves in River Channels EM1110-2-1409 Appendix V

Manning's friction formula neglecting the effect of debris. The Manning's coefficient of friction for each stream cross-section was determined by field reconnaissance and the relation of known data to Manning's formula. Separate coefficients were determined for the channels and the overbank portions of the sections. Backwater profiles were started from Station 290+00 just upstream of the Medway Woolen Mills Dam.

A. <u>The Escoffier Graphical Method</u> combines the Manning and Bernoullis equations and the equation for a given reach takes the following form:

$$Z_u - Z_l = Q^2 (F_u'' - F_l')$$

Where Z_u and Z_l are the water surface elevations upstream and downstream, respectively; Q is the discharge through the reach; F_u'' equals $F - L_l K/2$; and F_l' equals $F + L_u K/2$. F is defined by the equation $K/\ K_c(2gAc)$, where K & K_c are the conveyances of the total section and channel, respectively and A_c is the cross sectional area of the channel, L_l and L_u are the lengths of the reaches above and below the section, respectively.

B. <u>Bridge Losses</u>: Head losses at bridges not submerged were computed on constriction losses according to the formula:

$$h = C_c \left(\frac{V_c^2 - V_A^2}{2g} \right)$$

Head losses for bridges with submerged inlets and open outlets were computed on constriction losses according to the formula.

$$h = \frac{V_c^{\,2}}{2gC^2} - \frac{V_A^{\,2}}{2g} + h_f$$

Head losses for bridges with submerged inlets and submerged outlets were computed on constriction losses according to the formula:

$$h = \frac{V_c^{\,2}}{2gC^2} \left(1 + \frac{29C^2n^2L}{R^{4/3}}\right)$$

LEGEND

C = coefficient of discharge

G = acceleration of gravity = 32.2 ft. per sec. per sec.

h_f = head loss, in feet, due to friction

H = height, in feet, of average piezometric head at any section above the invert of the culvert or weir

L = length of constriction, in feet

n = Manning's roughness coefficient

Q = discharge, in cfs.

R = hydraulic radius of section of flow

V = velocity of flow at section designated by a subscript

V_a = velocity of flow approacing culvert or weir

V_c = velocity of flow through constriction

C. Dam and Overtopped Bridge Embankment Discharges:

Discharges for dams and for submerged overtopped bridge embankments were computed using Villemonte* formula for submerged weirs as follows:

$$Q = \left[1 - \left(\frac{H_2}{H_1}\right)^{3/2} \right]^{.335} Q_1$$

In the cases of dams and overtopped bridge embankments with free discharge, the discharges were computed using the broadcrested weir formula:

$$Q = CL \left(H + \frac{V_A^2}{2g}\right)^{3/2}$$

Where the embankment of a bridge is overtopped, the total discharge for the section is equal to the discharge over the embankment as computed by either of the two methods above plus the discharge through the opening computed by the corresponding constriction loss equation.

. Estimated Limits of Flooding: The approximate limits of flooding for the August 1955 flood, the Intermediate Regional Flood, the March 1936 flood, and the ten percent recurrent flood are shown on the maps (Plates 3 through 8) drawn from enlargements of U. S. G. S. topographic maps and interpolated from field surveys. They are approximate and should not be used for determination of flood lines for a specific property. Elevations from the profile should be used and must be translated to the actual ground to determine the depth of flooding of individual properties. This may be accomplished by utilizing standard survey methods and one of the nearby bench marks for reference. A summary of discharges and high water elevations at selected locations are tabulated in Table IV.

*King's Hydraulics Section 4

TABLE IV

SUMMARY OF DISCHARGES AND HIGH WATER ELEVATIONS

LOCATION / FLOOD	DOWNSTREAM OF POPULATIC POND STA. 100+00		BENT ST. BRIDGE STA. 191+00		SANFORD ST. BRIDGE STA. 224+50		MEDWAY WOOLEN-MILLS DAM STA. 226+00		SHAW ST. BRIDGE STA. 311+50		WEST MEDWAY DAM STA. 340+50		FRANKLIN ST. BRIDGE STA. 363+00	
	DISCH. C.F.S.	HIGH WATER ELEV.	DISCH. C.F.S.	HIGH WATER ELEV.	DISCH. C.F.S.	HIGH WATER ELEV.	DISCH. C.F.S.	HIGH WATER ELEV.	DISCH. C.F.S.	HIGH WATER ELEV.	DISCH. C.F.S.	HIGH WATER ELEV.	DISCH. C.F.S.	HIGH WATER ELEV.
10 PERCENT ANNUAL PROBABILITY	1170	132.7	1180	135.4	1170	150.9	1170	161.5	1000	166.7	810	172.1	580	174.2
MARCH 1936	1480	134.6	1700	137.2	165.0	152.3	1650	162.4	1360	167.6	1170	172.9	810	175.4
INTERMEDIATE REGIONAL	2320	136.5	3100	138.5	3100	153.8	3100	164.5	2915	169.0	2500	175.2	1635	178.2
MAXIMUM KNOWN AUGUST 1955	3150	138.5	3890	139.5	3790	154.7	3790	165.4	3520	170.0	3200	176.0	2015	179.8

GUIDE LINES FOR USE OF FLOOD PLAIN AND FOR REDUCING FUTURE FLOOD DAMAGES

General: A considerable amount of the flood plain of the Charles River is as yet undeveloped. As there has been up to now no flood protection measures taken along this portion of the river, the greater part of the flood plain is subject to flooding. Attention must be focused on safeguarding existing structures from flood damages and on regulating the type of future development. Existing structures may warrant protection by structural works of improvement (i.e., walls, dikes, or channel improvements) if economically feasible or by flood-proofing measures. Protection of future developments is contingent upon regulations governing the type of development permissible consistent with optimum economic use of the land within the community. Regulations administered by a municipality should have a sound technical and legal basis so as to preclude misuse of the flood plain which in time of flood could result in damages affecting the economy of the entire community.

Development within the community should adhere to a general plan to meet the various needs of the residents. In some instances, development on the flood plains may be contemplated. Careful consideration should be given to factors both beneficial and detrimental to the economic feasibility of permitting development on flood plains. Too often, the detrimental effects are overlooked when estimating the value of developing a building site in the flood plain. Some of these detrimental factors which may not receive proper consideration are:

a. Effect of filling
b. Flood losses
c. Cost of protective measures
d. Cost of flood - proofing
e. Cost of insurance

It, therefore, appears that some sort of local guidance or control is desirable to insure that proper consideration is given to developing a flood plain. In addition, such control could prevent damage to innocent parties located upstream or downstream who could suffer through acts of others.

<u>Flood Plain Filling</u>: Regulations to control the filling of a flood plain are most difficult to define. This difficulty arises unless a complete long-range plan of development for use of the flood plain has been evolved. In general, applications for filling are reviewed on a piece-meal basis which independently may not appear serious, yet combined could aggravate the flood problem of a community.

The problems of filling are two-fold. First, the filling of a flood plain can reduce the area of the cross-section of the valley and produce a restriction to flood flows, thereby raising the river stages upstream for any given discharge. Secondly, the filling can aggravate conditions downstream. This happens when the filling of a swamp or marshy area is permitted. In this case, the valley is generally very broad so it is possible to fill and still leave a waterway area large enough for the passage of a flood without increasing river stages upstream. However, the act of filling has eliminated a natural flood control reservoir which has benefitted downstream communities. This loss of natural storage means that in a recurrence of a particular storm, the runoff potential has increased, thereby creating a higher discharge downstream. Filling, if uncontrolled could eventually worsen downstream floods. Therefore, any potential filling should be analyzed for its effect on conditions both up-stream and downstream.

Flood Plain Regulations: Both channel encroachment lines and flood plain zoning should be established to reduce future flood damages. The ultimate goal of these regulations is to provide for the highest type land use consistent with the flood threat. These controls can be implemented by the use of specific regulations, such as subdivision regulations, building codes and local ordinances. For these controls to be effective, it is necessary that there be public understanding of the general problem, degree of risk, and the available alternate actions. The regulations must be clearly defined so that any land ower involved can evaluate the benefits he will derive along with the rest of the community.

Channel Encroachment Lines: The establishment of channel encroachment lines regulates any activity, building, filling or encroachment within such lines which could impede the free discharge of the stream or reduce channel storage, thereby causing harm to others.

Flood Plain Zoning: At such time as the Town of Medway establishes zoning by-laws, one of the provisions should include flood plain zones. The Town is granted that authority under the Zoning Enabling Act of the General Laws of the Commonwealth of Massachusetts as previously mentioned. References for procedures in establishing such an ordinance are listed in the Bibliography. The best long-range use of land and the area development should be the aim of such an ordinance. This can be developed through studies by local planning groups. Recognizing the degree of risk involved, consideration should be given to retaining land adjacent to the river for open space use, such as parking areas, parks, and recreation areas. Any structure permitted should be of the type that would not normally be used for habitation and could be submerged without serious consequences. On the higher elevation of the flood plain, structures for commercial or industrial use might be permitted, provided that the structure is not of such size to be a serious encroachment on the cross-section of the valley and provide that the first usable floor is above the limit of prescribed elevation.

Sub-Division Regulations: With zoning regulating use of the flood plain, sub-division regulations should be established to minimize the flood hazards to uses permitted in the flood plain.

Building Codes: Local building codes and Planning Board Regulations should be developed to enforce the requirements of minimum elevation for first floors or basements. These rules could provide a minimum requirement concerning the safety of the structure for the preservation of life and health. This can be accomplished by requiring that a permit will not be issued for construction in a flood prone area unless the hazard is eliminated by providing adequate drainage facilities, by a protective wall, by suitable fill, by raising floor levels of the buildings, by flood-proofing, or by combinations of these methods.

Municipal Use: One way of controlling the flood plain use is for the Town to acquire land as it becomes available and to convert to recreational or other uses which would not experience significant damage by periodic flooding.

Flood-proofing of Structures: There is much that individual owners can do to reduce flood damages to commercial and industrial properties that are presently located in the flood plain. Some of these measures are:

a. Controlling seepage through walls
b. Installing gates and valves on sewer and drainage lines
c. Anchoring of small or light structures to foundations
d. Permanently closing unnecessary openings in walls
e. Protecting foundations of buildings which might be subject to undermining
f. Protecting interior contents by elevating, covering or coating
g. Preparing schedules for evacuation of movable contents

Financial Control: Banks and financial lending institutions can assist in controlling development in the flood plain by denying funds for development or construction in flood prone areas. Similarly, insurance companies can limit their coverage of structures existing or proposed for construction in the flood plain.

. Flood Warning: The officials of the Town should take the necessary steps to make sure that there is an adequate warning system in the Town. Staff gages installed at major bridges could be the basis of such a system. As far as flood forecasting is concerned, the U. S. Weather Bureau is the agency responsible. The Weather Bureau Regional River Forecast Center is located at Bradley Field, Windsor Locks, Connecticut.

. Channel Maintenance: Another effort by which the Town could help keep the level of the floods down is to maintain continuous surveillance of the stream to prevent unauthorized dumping, remove fallen trees that may become temporary debris dams and keep bridge openings clear of debris or vegetative growth.

CONCLUSIONS

General: The report and accompanying drawings indicate the flood plain areas subject to potential flood damages. Judicial use of this information in implementing proper flood regulations can be of great value in achieving orderly future growth of the community and preclude the need for additional costly flood control improvements.

Remi O. Renier
Colonel, Corps of Engineers
Acting Division Engineer

GLOSSARY

BUILDING CODE: A collection of regulations adopted by a local governing body setting forth standards for the construction of buildings and other structures for the purpose of protecting the health, safety and general welfare of the public.

CHANNEL: A natural or artificial watercourse with definite bed and banks to confine and conduct continuously or periodically flowing water.

DISCHARGE: (Rate of Flow) The quantity of water passing along a stream per unit of time such as cubic feet per second.

DRAINAGE AREA: The area (acres, square miles, etc.) from which water is carried off by a drainage system.

ENCHROACHMENT LINES: Lateral limits or lines along streams or other bodies of water, beyond which in the direction of the stream or other body of water no structure or fill may be added without a permit.

FLOOD: Any temporary rise in streamflow or stage that results in significant adverse effects in the vicinity.

FLOOD OF RECORD: Any flood for which there is reasonable reliable data, useful in technical analyses. Ordinarily, the term is used to refer to "Maximum Flood of Record".

FLOOD PEAK: The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

FLOOD PLAIN: The relatively flat lowlands adjoining a water-course or other body of water subject to overflow therefrom.

FLOOD PLAIN REGULATIONS: A general term applied to the full range of codes, ordinances and other regulations relating to the use of land and construction within flood plain areas. The term encompasses zoning ordinances, sub-division regulations, building and housing codes, encroachment laws, open area regulations, health standards and other similar methods of control affecting the use and development of flood plain areas.

FLOOD PROFILE: (Backwater Profile) The longitudinal profile assumed by the surface of a stream of water flowing in an open channel.

FLOOD PROOFING: A combination of structural changes and adjustments to properties subject to flooding, primarily for the reduction or elimination of flood damage.

FLOOD VOLUME: The total volume of run-off during a flood, which is equal to the average rate of flow multiplied by time (flood duration). The term "inches run-off" is sometimes used to designate flood volume, which means that the flood volume would cover the drainage area above the point of measurement to a uniform depth equal to the number of inches specified.

FLOODWAY:

(1) Designated: The channel of a stream and that portion of the adjoining flood plain designated by a regulatory agency to provide for reasonable passage of flood flows.

(2) Natural: The channel of the stream or body of water and that portion of the flood plain that is used to carry the flow of the flood.

GAGE:

(1) A staff graduated to indicate the elevation of a water surface.

(2) A device for registering water levels.

GAGING STATION: A selected section in a stream equipped with a gage and facilities for measuring the flow of water; a place on a stream where data are gathered by which continuous discharge records may be developed.

HISTORICAL FLOOD: A known flood which occurred before systematic record-keeping was begun for the stream or area under consideration.

LEVEE: A dike or embankment for the protection of lands from unundation.

MAXIMUM KNOWN FLOOD: The largest known flood which has occurred in a region whether it is an historical flood or a flood of record.

SUBDIVISION REGULATIONS: Regulations and standards established by a local public authority, generally the local planning agency, with authority from a State Enabling Law, for the subdivision of land in order to secure coordinated land development, including adequate building sites and land for vital community services and facilities such as streets, utilities, schools and parks.

WATERSHED: The area drained by a stream or stream system.

ZONING ORDINANCE: An ordinance adopted by a local governing body, with authority from a State Zoning Enabling Law, which under the police power divides an entire local governmental area into districts and, within each district, regulates the use of land, the height, bulk, and use of buildings or other structures, and the density of population for the purpose of protecting the health, safety and general welfare of the public.

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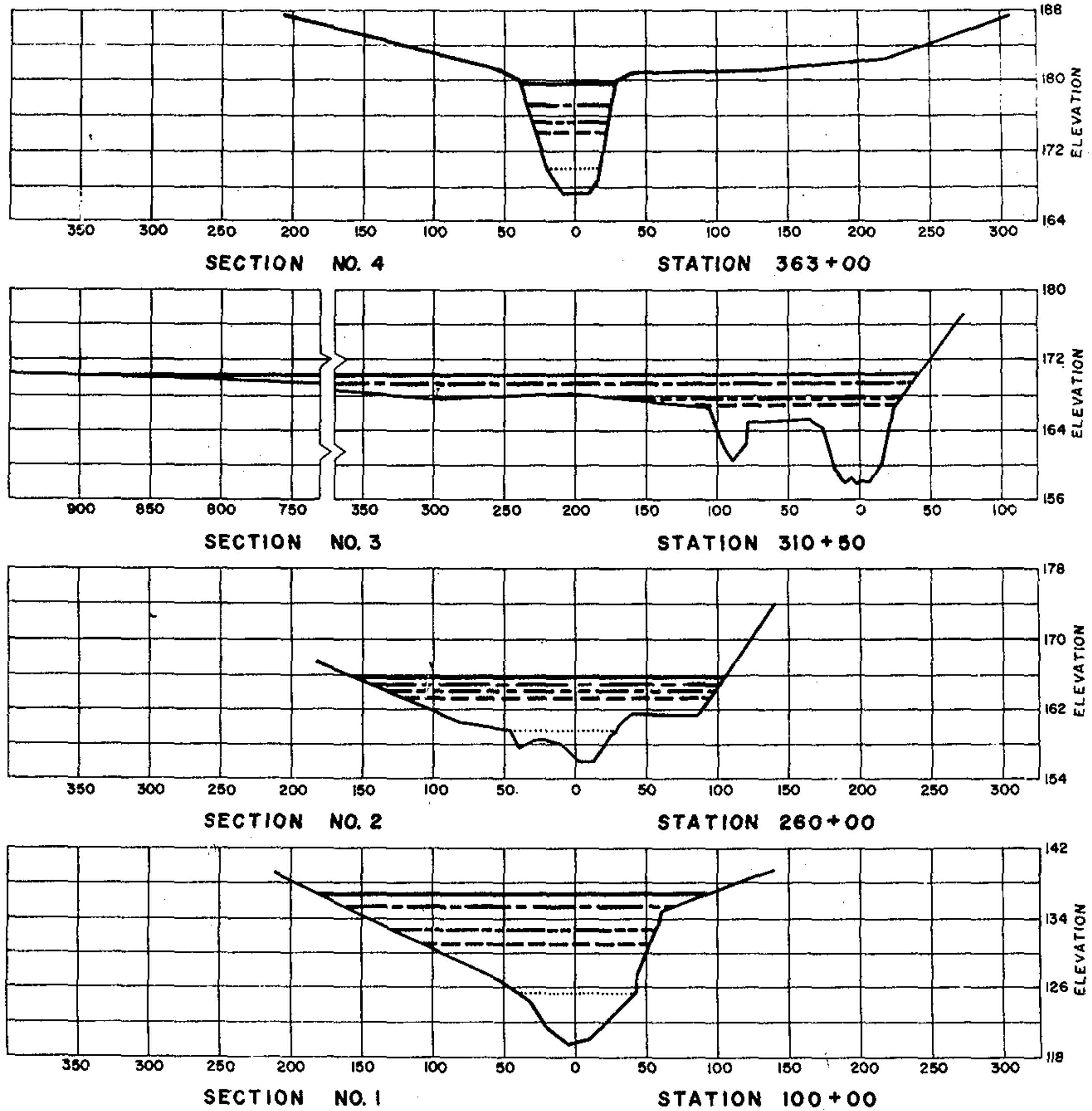
Cola F/O

Mike

9

Plate 1 thru 9



NOTE: SECTIONS TAKEN LOOKING DOWNSTREAM
HORIZONTAL DISTANCE IN FEET
ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

LEGEND:

MAXIMUM KNOWN FLOOD (AUG. 1955)
INTERMEDIATE REGIONAL FLOOD
MARCH 1936 FLOOD
10% PROBABILITY FLOOD
NORMAL WATER SURFACE

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MEDWAY, MASS

TYPICAL CROSS SECTIONS

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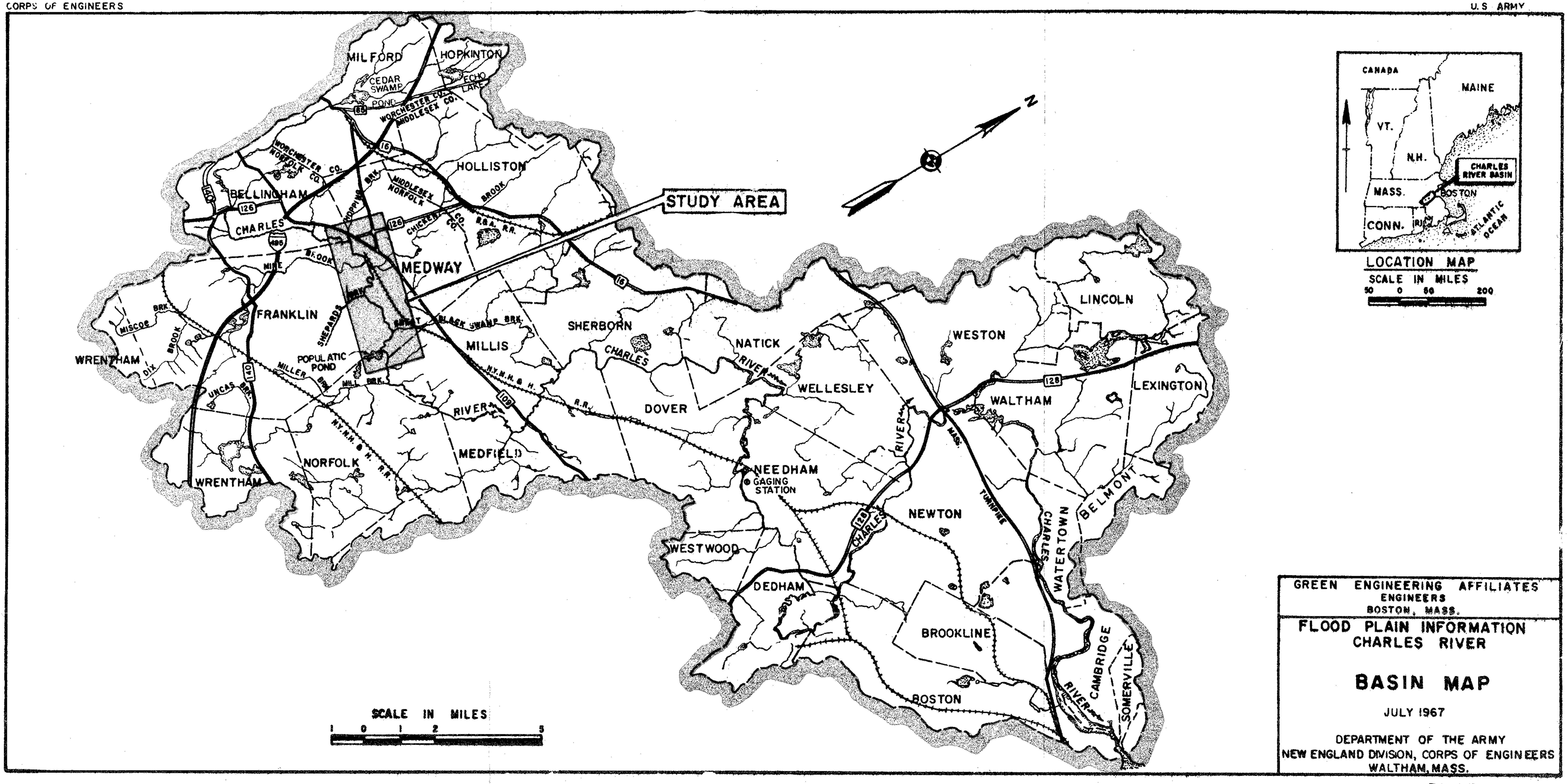
PLATE NO. 10



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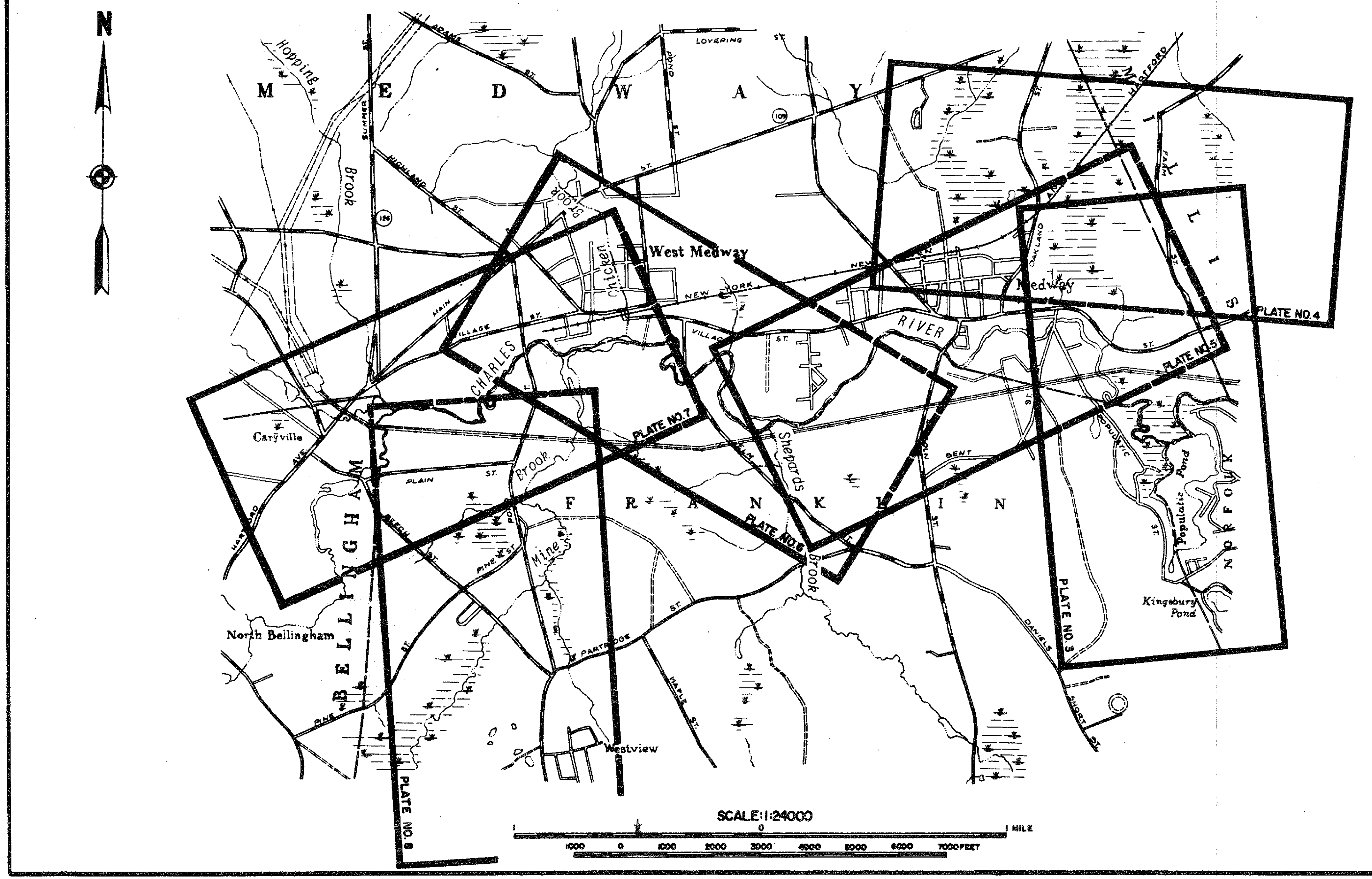

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INDEX MAP

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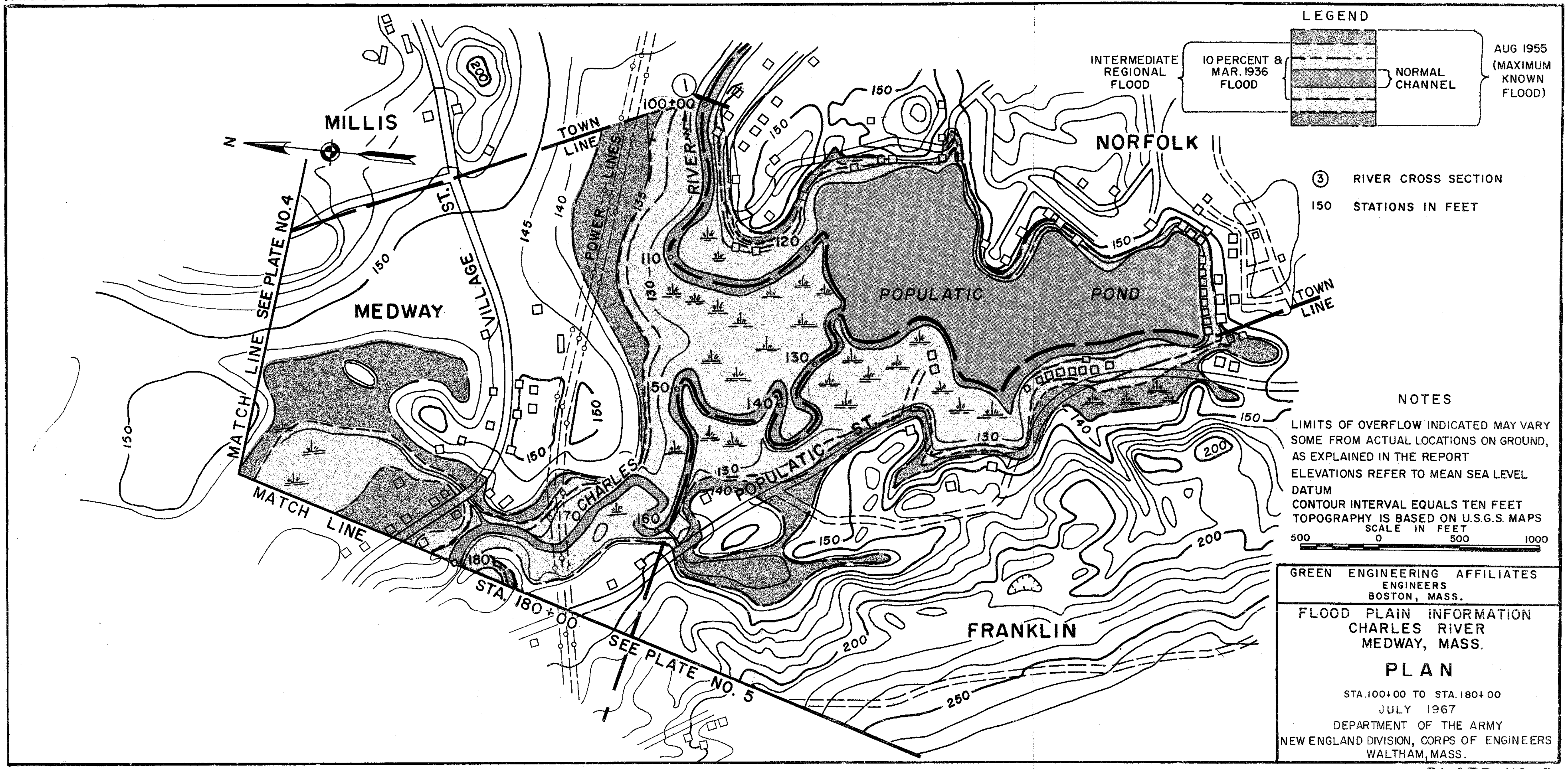

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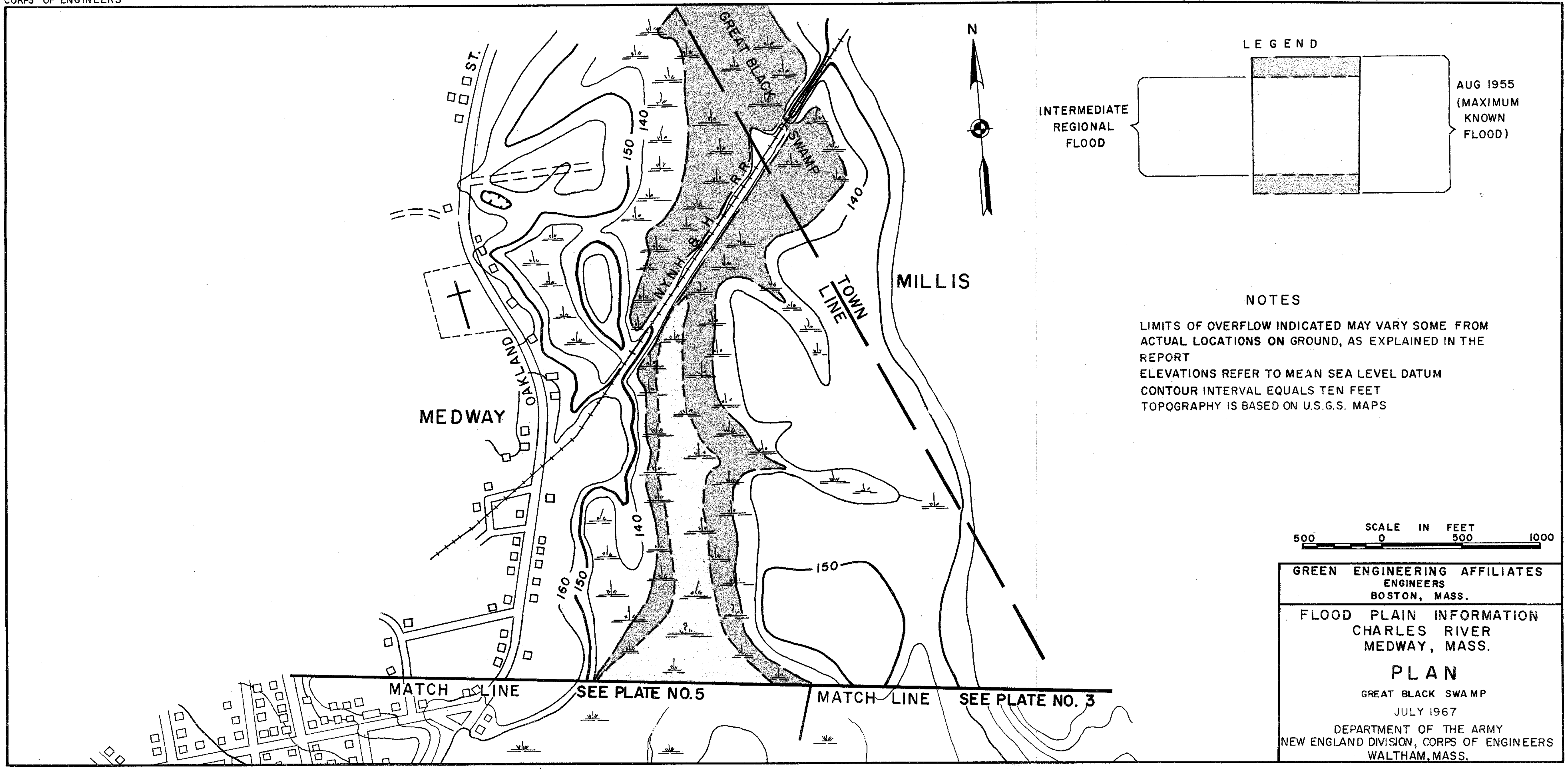

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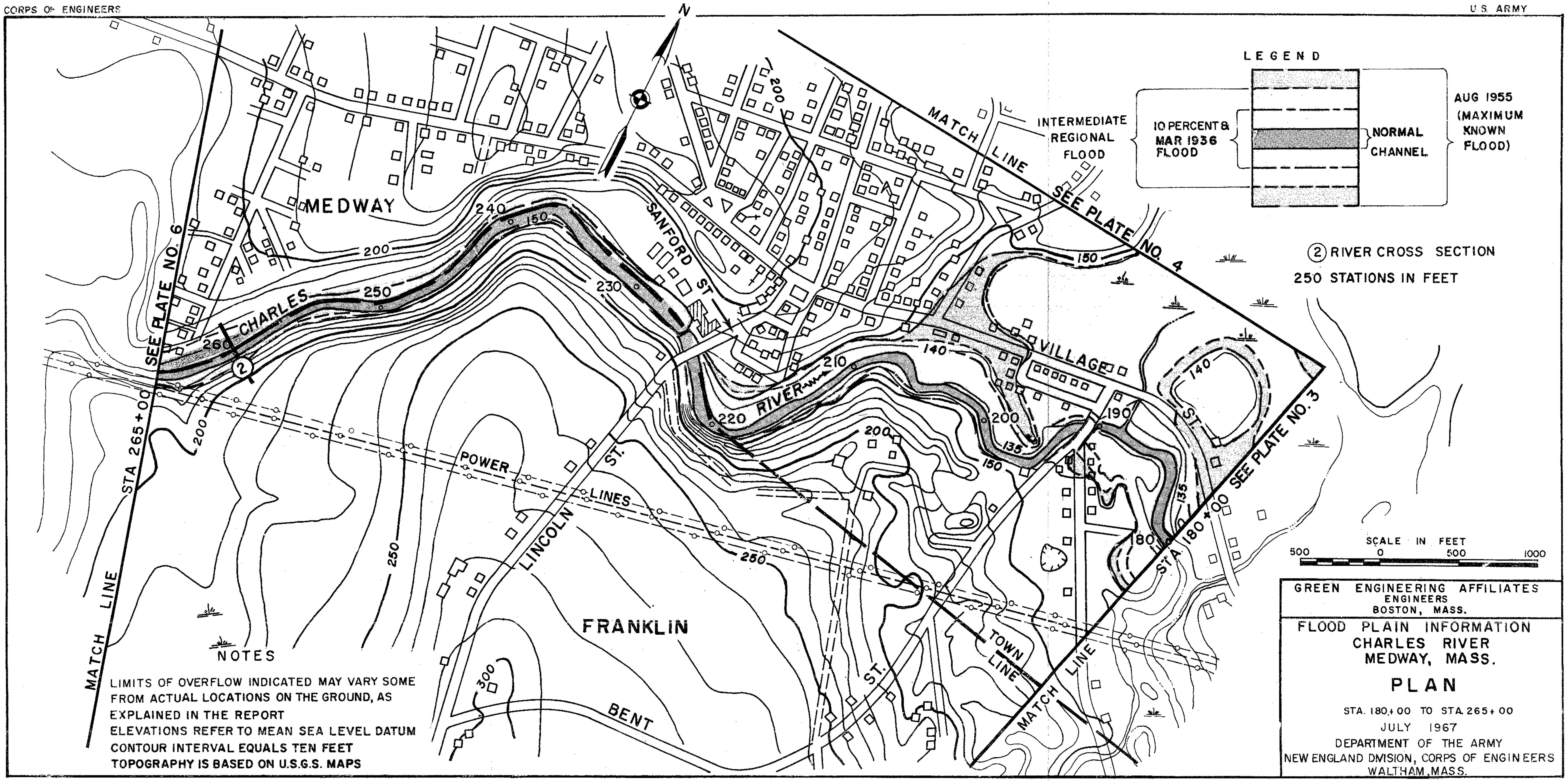

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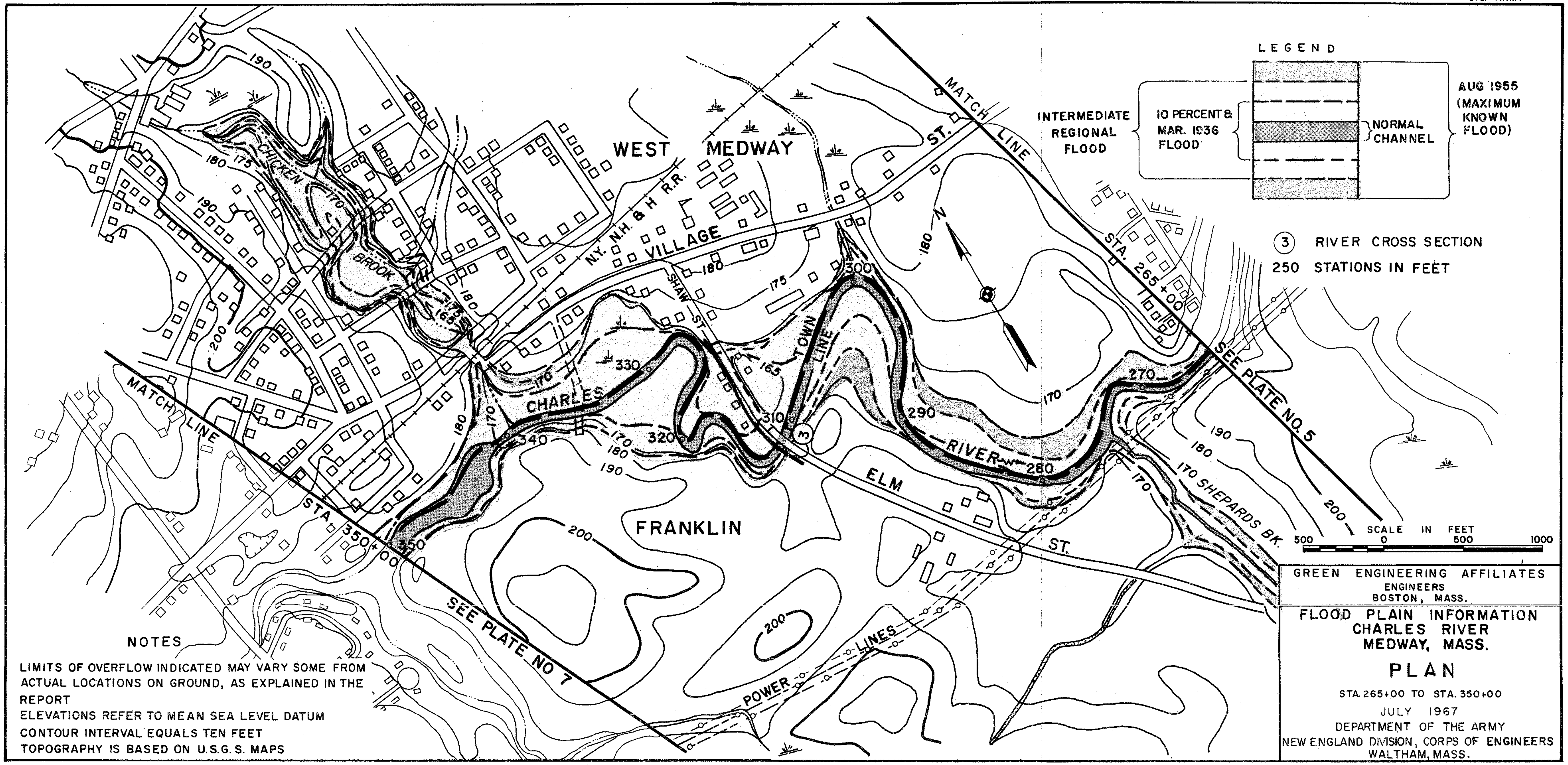

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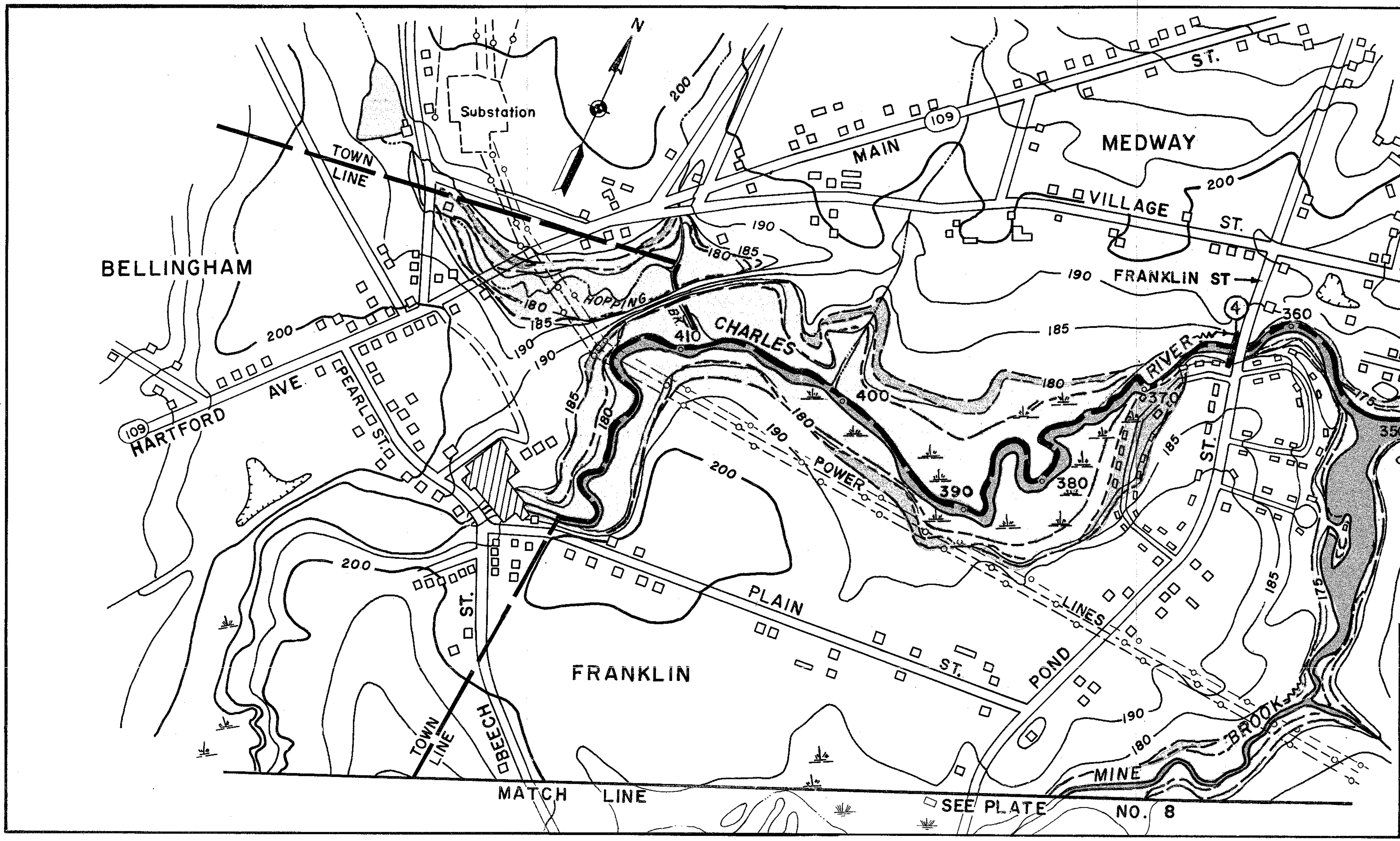

FOR LEGEND AND NOTES
SEE PLATE NO. 6

SCALE IN FEET
500 0 500 1000

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PLAN
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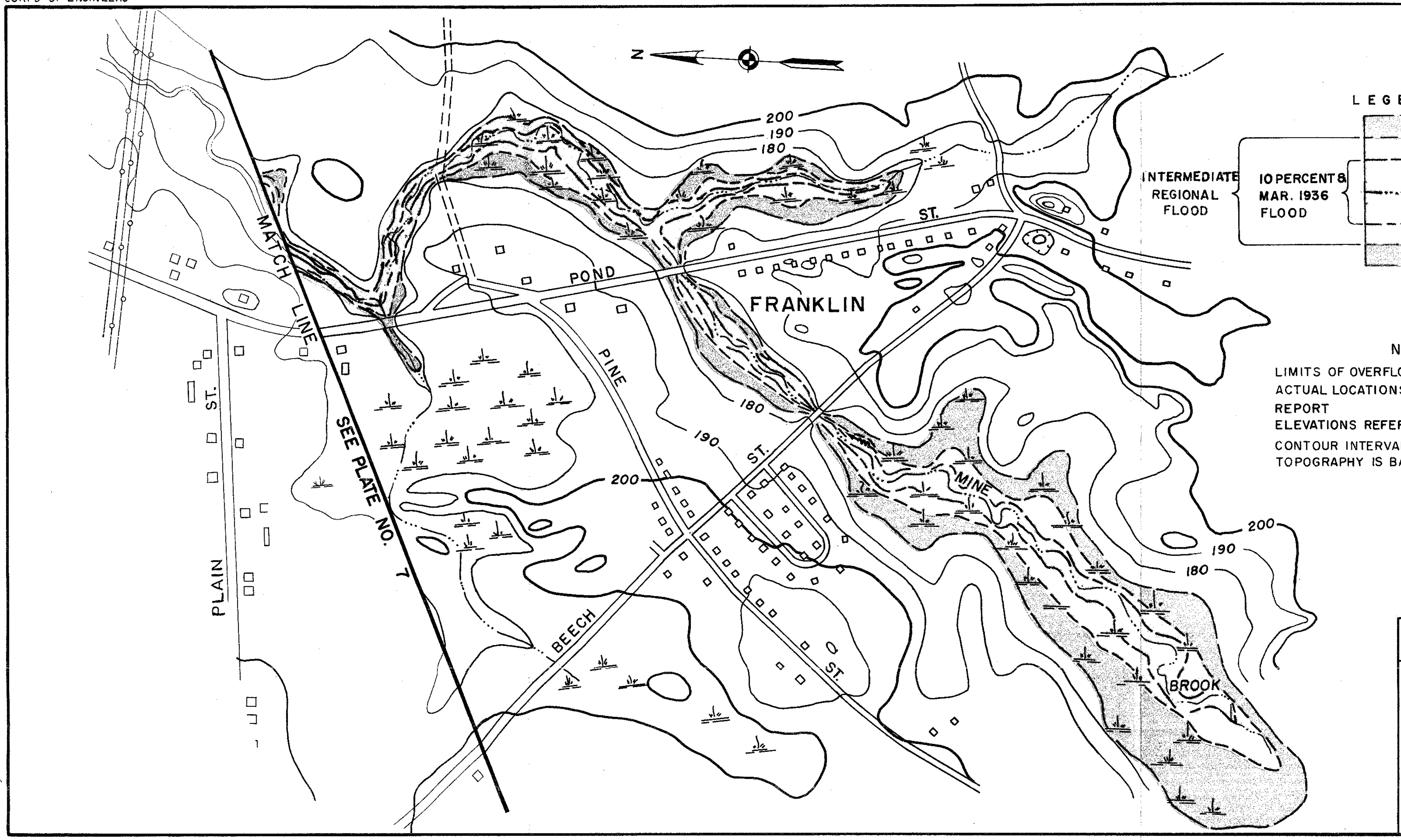

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MINE BROOK
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PLATE NO. 8

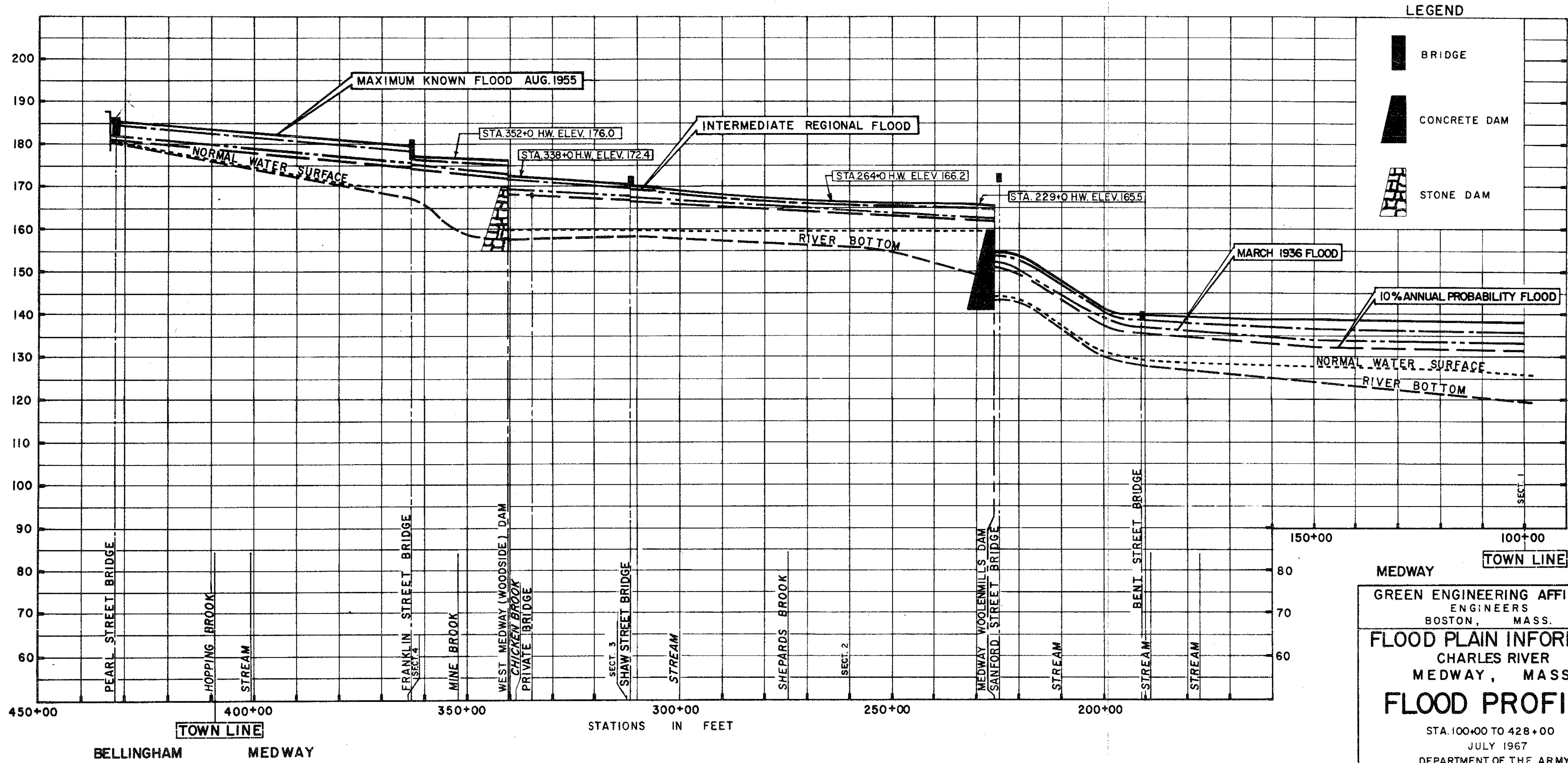

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PLATE NO. 9